Update on Calibration of Nearby Supernovae Sample

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This short note describes the current state of the nearby 99 analysis. The first section discusses the analysis steps completed before Val Prasad's trip to France, while the second part of this note presents the work accomplished in collaboration with Nicolas Regnault while in France. The final section of this note discusses what needs to be undertaken in order to reach a satisfactory scientific result.

1 State of Analysis Prior to France Visit

The first stage of the calibration process is to form a tertiary star catalog based on the images and nights where calibration data was taken. The code for analyzing this data as well as forming the tertiary standard catalog is completed and tested. A tertiary star catalog was created using the calibration images present in the TOADS image database. All 5 bands, U, B, V, R and I, were calibrated.

The TOADS database is a database of images after flat-fielding, baseline subtraction and amplifier gain correction. There is a one-to-one correspondence between the original ("raw") images taken while observing and the images in the TOADS database.

The second stage of the calibration is to calibrate the stars in all the images containing the supernovae. This includes calibrating images on nights on which no calibration data was taken. The code for this is completed and tested and calibration constants (zero points and colour/filter correction terms) were determined for the images that were found in the TOADS database.

However, $\sim$10% of all followup images in the TOADS database were not processed or calibrated for reasons not fully understood by us at the time. These included images from the MLO, Marly, WiYN and Keck telescopes.

2 Work Accomplished in France in collaboration with Nicolas Regnault

The main thrust of the work performed in France involved cleaning up the TOADS database so that every "calibrate-able" image could be calibrated and every image that could not be calibrated was accounted for. It was important to be able to account for every image in the database because, as discussed earlier, there were several images that were not being calibrated and it was not clear if this was because the images were of poor quality (e.g. low signal-to-noise) or if there were pathological

features in the calibration code. The "cleaning-up" of the database required several steps to be completed. These were :

- identifying all stars and galaxies in all followup images
- matching each object within each image to the USNO catalog
- determining if the transformations from pixel coordinates to WCS coordinates for each image was correct. Images whose WCS-to-pixel-coordinate transformations could not be determined for several reasons including :
  - the objects not being identified clearly due to low signal-to-noise
  - images with too few objects to accurately determine the transformations
  - images with poor astrometry

  were identified and not used in the calibration.
- identifying the supernova within each image. Images in which the supernova could not be accurately identified were not used in the calibration.
- identifying images with other processing issues such as flat-fieldiing problems. Images with severe processing issues were not used in the calibration.
- producing a fiducial list of stars for each image that is used in the calibration. This step is essential for the calibration since it assigns a specific star identification number to each object within the image such that the same object in different images will have the same star identification number.
- performing a Moffat-based PSF photometry on each fiducial object within all "calibrate-able" images. A list of instrumental fluxes was generated for each object where the photometry was successfully determined. This list is then used in the calibration.

3 What Next?

3.1 Re-determination of Calibration Constants

Having "cleaned-up" the TOADS image database, the tertiary star catalog can be re-determined and the calibration constants for every "calibrate-able" image can be measured. This step is being carried out at the moment and is expected to be completed shortly.

3.2 Determination of Supernova Fluxes

The next stage in the calibration is to determine the supernovae fluxes (supernova photometry). The supernovae fluxes are then combined with the previously-measured calibration constants to obtain the lightcurves for each supernova.

The fluxes for 14 of the 20 supernovae had been determined by Nicolas Regnault during his thesis work. The fluxes were determined, however, in the B, V, R and I bands only. A summary of the photometry of the 20 supernovae in the nearby 1999 sample is presented in Appendix A. Of the 14 supernovae that were processed, the fluxes for 3 of the supernovae were determined by fitting a Moffat PSF to the supernova. 3 other supernovae were processed by simultaneously fitting a model of the galaxy (as obtained from the reference images) and a Moffat PSF, while 8 supernovae were processed using an Alard subtraction.

Originally, it had been assumed that we would use the fluxes given in Regnault's thesis together with the calibration constants determined with the latest multi-setup calibration to obtain the lightcurves. Unfortunately, it was recently pointed out that the supernovae fluxes in Regnault's thesis were based on a set of composite images. These composite images were formed by combining one or more "raw" images. It is essential to know the composition of each image in the Regnault-thesis database because

- the Julian date given in the header of each composite image is not accurate. In some cases, the Julian date in the composite image header is thought to be accurate to within 1.5 days while in some other cases, the Julian date could be either 100 or 200 days different from the true Julian date.
- the same objects in different images do not have a common, unique star identification number.

In order to relate the Regnault-thesis images to the TOADS images, one must know the elements of each composite image. Unfortunately, the exact relationship was not saved in the composite image header and cannot be retrieved easily. Using the latest "cleaned" TOADS database, Nicolas Regnault has tried to associate the composite images to the TOADS images by comparing the composite and TOADS images for the same band and telescope setup. By applying loose selection cuts on the information given in the composite and TOADS image headers, he has tried to match the composite images to the TOADS images. The selection cuts are based on the airmass and Julian date. Unfortunately, this technique is clearly not robust as several composite images can be related to the same TOADS image or the wrong association can be made. Furthermore, even if the correct night is identified, there is an uncertainty of several hours in the determination of the Julian date.

Using the supernovae fluxes provided in Nicolas Regnault's thesis presents the following difficulties:

- possible incorrect determination of the Julian Date
- possible incorrect assignment of the star identification number
- irreproducibility of supernovae fluxes

This leaves us with several options to proceed with the calibration of the supernovae fluxes and lightcurves. I list below the options and comment on each option.

1. Re-determine all the supernovae fluxes for supernovae using the TOADS database. This requires either writing new photometry code or locating any existing supernova photometry code and incorporating it into the TOADS framework. Since the supernovae photometry also involves

testing and debugging of the photometry technique and software, the re-determination of the supernovae fluxes for the supernovae could easily take up to 6 months or more. One option is to carry out the calibration in stages. We could first proceed with the calibration of 3 supernovae (99aa, 99ac, 99aw) which were previously processed using a Moffat-based PSF alone. These 3 supernovae are conceivably the easiest to calibrate and could potentially be done on a one-month timescale. The 3 supernovae which require a simultaneous fit of the host galaxy and PSF will take slightly longer but would follow the calibration of supernovae 99aa, 99ac and 99aw. Finally, the supernovae which require an Alard subtraction can be calibrated. Performing the Alard subtraction is expected to take the most amount of time ($\sim$3-5 months).

The advantages of this approach is that the photometry will be reproducible and will rely solely on a well-understood database. In addition, we will be able to determine the lightcurves for another 3 supernovae (99be, 99bh, 99by) besides the 14 supernovae described in Regnault's thesis. However, the drawback is that calibrating all 17 supernovae will take a significant amount of time.

2. Use the images associations performed by Regnault. We could proceed by using the fluxes presented in Regnault's thesis together with the recently-determined image associations. Any data points that are very likely to be due to an incorrect image association could be excluded and the supernovae lightcurves can be compared to those in Regnault's thesis as a cross-check.

   The advantage of this approach is that the fluxes and associations are already present. The drawback is that one will still not be sure that the composite images have been correctly associated with the TOADS database leading to uncertainties in the supernova epoch of 1.5 to 100 or more days. Applying a very stringent image association cut may result in a loss of a significant fraction of lightcurve points.

3.3 Lightcurve Fitting

Once the supernovae fluxes have been determined, it is necessary to fit the data points, at least 2 bands at a time, in order to determine the lightcurves. The fitter for this is being worked on at the moment and should be ready soon.

3.4 Other Remaining Issues

The remaining issues in the calibration of the nearby 99 dataset are the understanding and assignment of systematic uncertainties and the determination of the supernovae fluxes in the U-band. Systematic studies will be undertaken once the lightcurves have been produced.

U-band photometry is being pursued by collaborators in Lisbon, Portugal. They are currently using a DAOPHOT-based (Stetson, 1992) photometry. If this photometric technique is successful in calibrating the U-band images, then it should be performed on the rest of the images in the B, V, R and I bands.

4 Conclusions

We have been successful in producing a clean and well-understood database of images for the nearby supernovae sample collected in 1999, greatly facilitating the calibration of the dataset. We have almost completed the determination of the calibration constants for all useable U, B, V, R and I-band images in the TOADS database.

However, difficulties in the accurate determination of the supernovae fluxes in the B, V, R and I bands means that we need to decide on how to proceed with the supernovae lightcurve calibration.

Meanwhile, a multi-band supernova lightcurve fitter is being developed at LBNL and U-band photometry is being studied in Lisbon.

A Summary of Supernovae Photometry in Regnault Thesis

In this appendix, we list the 20 supernovae in the 1999 nearby supernovae data sample and describe the status of the calibration as performed by Nicolas Regnault in his thesis.

Supernova	Status of Calibration
1999aa	Calibrated using Moffat-based PSF only
1999ac	Calibrated using Moffat-based PSF only
1999aw	Calibrated using Moffat-based PSF only
1999ao	Calibrated using simultaneous fit of galaxy and SN
1999bk	Calibrated using simultaneous fit of galaxy and SN
1999bm	Calibrated using simultaneous fit of galaxy and SN
1999ar	Calibrated using an Alard subtraction
1999au	Calibrated using an Alard subtraction
1999av	Calibrated using an Alard subtraction
1999ax	Calibrated using an Alard subtraction
1999bi	Calibrated using an Alard subtraction
1999bn	Calibrated using an Alard subtraction
1999bp	Calibrated using an Alard subtraction
1999bq	Calibrated using an Alard subtraction
1999as	**Not** calibrated. Identified as a hypernova 1c (Hatano,2001)
1999at	**Not** calibrated. Identified as **not** a SN
1999be	**Not** calibrated. Fluxes could not be read. Can be reprocessed now.
1999bf	**Not** calibrated. z=0.24. Too far away and not enough images.
1999bh	**Not** calibrated. No reference present in 1999. Can be reprocessed now.
1999by	**Not** calibrated. No reference present in 1999. Can be reprocessed now.